some apology. I cannot, however, entirely fall in with his line of argument. Their frequent vagueness may possibly on occasions have saved us from war, but it seems to me that it has far more often brought us to the very edge of war, if not actually into war.

We have had some curious instances given us to-night. It throws an odd light on the psychology of nations, or their rulers, when we are reminded that the United States were once not too proud to be ready to fight for a small Pacific island! When we hear of such incidents as the way in which the boundary of Uganda and the Congo State was drawn along an unascertained line of longitude we cannot but feel that the diplomatists had better have consulted geographers and travellers before they committed themselves on paper. Their traditions stood in the way: what these traditions were I may best illustrate by a personal anecdote. Some years ago, while I was one of the Honorary Secretaries of the Society, I received an official letter from the Foreign Office signed by the then Secretary of State and sent in reply to a protest made by the Council against the exclusion of Geography from the subjects for examination for Foreign Office clerks. The gist of the letter was, that all the geography needed by a Foreign Office clerk could be picked up in his first few months in the Department.

Again I call to mind how one of our most distinguished Proconsuls, the late Sir Lambert Playfair, told me that only once on his many returns from foreign posts had he been met on reporting himself at the Foreign Office by anyone who cared to ask questions and listen to his replies. The exception was our frequent guest, Lord Bryce. I remember too a chance meeting with Sir John Kirk, when he exclaimed, "My life's work in Africa has just been given away in London." To-day we can reflect with satisfaction that General Smuts is putting that right, and that Kilimanjaro, the top of Africa, is no longer a German mountain!

I would not deny that there is something to be said in excuse of the official attitude. It is hard on statesmen to be called on to give their attention to details in matters which are alien to their usual interests. But where the political or military business in hand is seriously affected by geographical facts and considerations these must be taken into account under pain of disastrous consequences. It is needless to give recent instances. This war will make many changes; may we hope that among them will be a change in our official attitude, and that we shall learn to think geographically as well as imperially.

I must add, in conclusion, one word of thanks to my old colleague Sir Thomas Holdich for having come at very short notice to our rescue and given us such a masterly discourse.

NIGHT MARCHING BY STARS.

E. A. Reeves.

Read at the Afternoon Meeting of the Society, 13 *April* 1916.

THE subject which I have been asked to bring before you this afternoon is doubtless one of the oldest with which we could possibly deal. The heavenly bodies have from the earliest days been the natural guides of the traveller. Long before the magnetic compass was known, at any rate in Europe, men found their way across unexplored oceans and trackless deserts by the sun by day and the stars by night; and the same guides are used by nomad tribes at the present time. So long ago as the seventh century B.C. Thales, the Greek philosopher, had taught the Ionian sailors to use the stars and to steer by the Little Bear, like the Phœnicians.

As centuries passed and the magnetic compass began to be generally used, it appears that this time-honoured method of finding the way about gradually became superseded, and instead of the heavenly bodies serving as ready guides for rapid marching, their use has, in civilized countries, been confined almost entirely to instrumental observation for fixing positions of definite points.

It is, of course, impossible to overestimate the value of the magnetic compass, and I should like to state at once that in my opinion star marching should be considered more as a means supplementary to ordinary compass marching than as rivalling it. Still the compass is not always at hand, and often most unreliable when it is. In any case a man cannot go along with his eye fixed on the compass card the whole time, and must have distant points to march on. In the daytime mountain tops and other terrestrial points are chosen, the compass bearings of which have been previously found, but when it is dark these are of course invisible, and some luminous marks are necessary, the most serviceable of which are those provided by Nature, the infinitely distant stars.

If a man has a sufficient knowledge to use the heavens as a compass at night, he is not dependent on his magnetic compass; and if, as frequently is the case, specially during military operations, he finds himself without a compass, or that it is not to be relied upon, he never need go in an absolutely wrong direction, as I know has frequently happened. On several occasions during this present war I have been told by those who know that men have, with the stars shining around them, mistaken their direction and marched straight into the arms of the enemy, thinking they were going to their own people. Now there is no need for this sort of thing to happen, and very little practical instruction beforehand should have prevented such mistakes. I have during the last few months occasionally been asked to lecture to troops in training, and have found that they readily pick up sufficient knowledge to march by the stars.

What it really comes to is that a man who can properly use the stars for marching has, on any starlight night, instead of a little compass card measuring only an inch or two in diameter, the whole vault of heaven for his compass.

Still, after all, this only furnishes another means of determining direction just as the compass does, and it cannot, any more than that, guide a man unless he knows what direction he wants to march in. Not long ago a man wrote to me to ask how, if he got absolutely lost on a dark night and did not know which direction he ought to go in to reach his destination, he could find this out by the stars. I had to inform him that there was no such magical influence that I knew of in the stars, but if he knew whether he ought to go north, south, east or west, the stars would point out that direction for him.

It is satisfactory to find that there is now an increasing interest in this subject, and several officers, realizing its great practical importance, have published tables and practical instructions that should be of considerable assistance.

Lieut.-Colonel W. A. Tilney (17th Lancers), who has devoted much time to the matter, was one of the first to direct my attention to the great value to troops of star marching, and the method which he worked out, after receiving instruction from me, was first used with excellent results a few years ago in India on long marches, and I understand has since been of considerable service at the front in France. It has been highly commended by military officers, and Sir Douglas Haig writes that the "method has been tested and found successful." Later on I shall refer to this and other methods of finding star bearings, but we will begin at the beginning and first of all see what is the nature of the problem that presents itself.

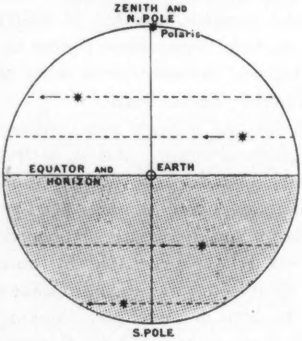


FIG. 1.

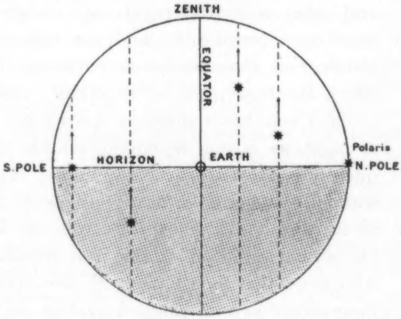


FIG. 2.

It is clear that if the stars were fixed points in the sky they would at once provide the necessary luminous marks for guidance at night, for having once learnt to identify them, or the brighter of them, we could use them just as we do landmarks in the daytime; but the trouble is that they are not fixed, and they appear in different lines of bearing at different hours of the night and seasons of the year for even the same place on the Earth's surface. This apparently complicated movement, combined with the supposed difficulty of identifying stars, has led many to suppose that the matter cannot be understood without a great deal of study, and they have therefore abandoned the idea of using stars for finding direction altogether. But this is entirely a mistake, as I feel sure that any who have given attention to the subject will admit.

In matters of this kind I always think it well to begin at the beginning, and I will therefore ask you to bear with me while I refer to a few elementary diagrams, so that we may see what really takes place; and after that I will deal with the various devices and methods for rapidly finding the bearings of stars at any time, and then endeavour to show how these bearings can be made use of for the purpose of marching even by those who have no knowledge of astronomy, except just enough to identify a few of the brightest stars.

Owing to the rotation of the Earth on its axis, the stars appear to pass round the heavens from east to west in twenty-four sidereal hours. In Fig. 1, suppose a man situated on the North Pole of the Earth, then the pole star, which is within about $1\frac{1}{4}^\circ$ of the celestial pole (*i.e.* the continuation in the sky of the Earth's axis of rotation), will be stationary practically over his head, and all the other stars will pass round him in circles. The horizon line will coincide with the equator, and the N. pole with the zenith. Only those stars north of the equator will be visible, there will be no rising or setting, and the altitude of any particular star will always be the same. Whichever way the man turns he will face south. The same holds good at the South Pole, except that there only the stars south of the equator could ever be seen, and the face must be always towards the North.

Next, in Fig. 2, suppose a man to be standing on the equator, then the pole star will be on his northern horizon, the zenith will be on the celestial equator, and the stars will pass in circles at right angles to the horizon. In this position all the stars would be visible at some time or other, if they were not intercepted by some obstruction near the horizon line.

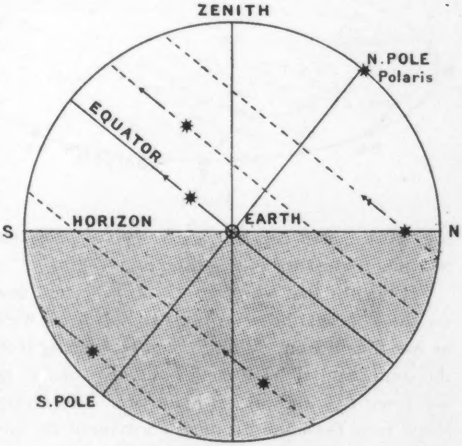


FIG. 3.

In any latitude between the equator and the poles the condition would be something like that shown on Fig. 3. The pole star would be practically stationary at the north pole in the heavens, at an angle above the horizon equal to the latitude of the place, and all other stars would describe circles in the sky as shown by the lines with arrows. Those near the North Pole would never go below the horizon, while those near the South Pole would never come above it. Any star exactly over the equator would rise due east and set due west, while all the others would rise at different bearings round the horizon-line as shown by the position where the star lines, with arrows, cut the horizon, and would set at corresponding angles on the opposite or W. side of the horizon. It will also be seen that all stars must be on the N. and S. line when they have reached their highest or lowest altitudes, that is when they are on the meridian. Fig. 3 represents the case for about the latitude of London. The next, Fig. 4, shows the same thing perhaps more graphically as a sort of bird'seye view.

It is important to remember that all stars rise and set exactly at the same bearing for the same place on the Earth, at any season of the year, although the time of their rising and setting, as shown by an ordinary mean-time watch or clock is constantly changing, and is nearly four minutes earlier every night, or about half an hour earlier every week. This is due to the Earth's path round the sun making the sun appear to move in a circle amongst the stars in a year.

It is surprising how few people know anything of even these elementary movements, and an officer to whom I was trying to explain something of the subject the other day appeared to think that the stars moved about all over the sky much as they pleased, with little or no common connection with one another.

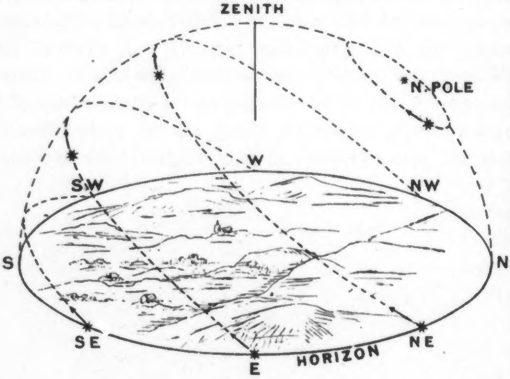


FIG. 4.

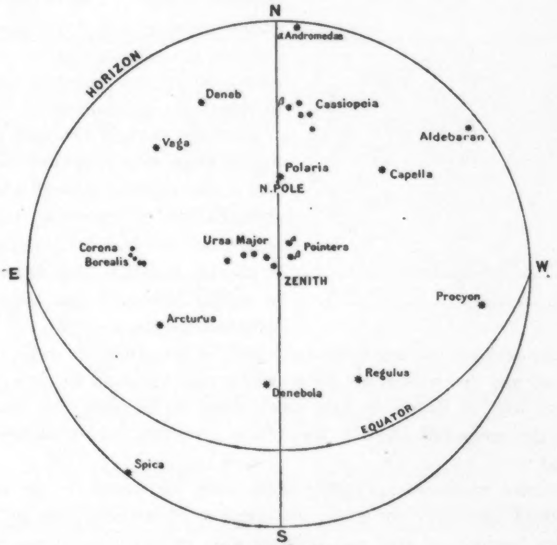
The lower the altitude of a star is the better for marching, so long as it can be clearly seen. At or near the zenith a star would be quite useless for giving direction.

It is clear that wherever a man is, except near the North Pole, if he can see the Pole Star he never need go hopelessly wrong in his direction, since if he has this in front of him he must be facing true north, his back is towards the south, and if he stretches out his arms at right angles his right hand will point east and his left hand west. Any other direction can be roughly found from these, and if more convenient the face may be turned towards the east or west by placing the outstretched arms north and south.

When the Pole Star is obscured there are rough ways of finding the north direction, of which those most frequently given in books are: (1) Follow the direction of the line of the two pointers (α and β Ursæ Majoris) of the Great Bear for about five times the distance these stars are apart, and the position indicated will be true north. (2) Imagine a line connecting the "W"-like stars in Cassiopeia with the pointers of the

Great Bear, and halfway across will be the north direction. (3) When the pointers are vertically above one another they are practically due north. (4) When Ursa Major is below the horizon the approximate direction of true north can be found by supposing a line drawn from α Andromedæ (Alpheratz) to β Cassiopeia, and producing it beyond the latter for a distance that these two stars are apart.

There are similar rough ways of finding the south direction, such as (1) suppose a line joining the two stars of the Southern Cross which are farthest apart and the point on the continuation of this line situated four and a half times beyond the brightest star the distance that the two stars are apart will be nearly due south; (2) imagine a line connecting β Centauri and Achernar, and the central point of this line will be nearly the true south direction.



April 15th 10 p.m.

FIG. 5.

These rules for finding bearings are all simple enough, and although they are only rough and approximate they have for many years proved of the greatest service to night travellers in the wild, who have had no compass or other instrument of any kind with them. Indeed in military operations too many a man has found them invaluable to him, as I have heard only just recently. But there are times, such as when the northern heavens are clouded over, when they are not available. Besides, what is wanted is a star in something like the direction of the march, and the problem is how to make use of any bright star for the purpose of marching.

The recent efforts of those who have taken the matter up have been specially directed to finding a simple method of doing this.

In Fig. 6 suppose NESW to be the horizon, and let NS be the true north and south line, or the meridian. Z will be the zenith, and P the north pole. Now suppose the star to be in the position indicated by ✱. Then A✱ will be the star's altitude, ✱Z its zenith distance, ZP the co.-lat. of the place, and P✱ the star's polar distance. The curved line P✱B will be the hour-circle passing through the star, the angle ZP✱ will be the hour angle of the star, or its distance in time from the meridian, and the angle PZA the star's true bearing or azimuth, as it is called, which it is required to find. This is one of the angles of the spherical triangle PZ✱, and in all accurate survey work is computed by the ordinary formulæ of spherical trigonometry.

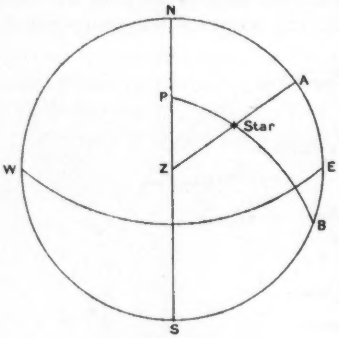


FIG. 6.

For the purpose of rapid marching by stars it is absurd to suppose that a man is going through a lengthy computation of spherical triangles before he can find his bearing, and so various attempts have been made to supply him with this angle with sufficient accuracy for use.

For any latitude the angle can be found by two different ways, that is, (1) by knowing the hour-angle ZP✱, which can be found for any time of the night, and so comes to the same thing as knowing the time; or (2) from the measured altitude A✱, which gives the zenith distance ✱Z of the star.

The tables in Colonel Tilney's little book are based on the first of these methods, and give for every five degrees of latitude from 40° N. to 55° N. the bearings of the most suitable stars for night marching for the first day of every month. These bearings are given for every hour of the night from 8 p.m. to 5 p.m., and are to the nearest five degrees; that is, none of them is likely to be in error by more than about 2°. He has also published similar tables for star marching in India, which have been of great service. A specimen of one of the pages of these tables will be found below. Clear examples are given to show how to use the tables, and there are star-maps at the end.

Colonel Tilney has, I understand, still further improved his methods quite recently, and I hope he will tell us something about this later.

There have been, of course, for years past, sets of Azimuth Tables obtainable for the use of navigators, but these are not suitable for rapid star marching.

Mr. J. Dundas White, M.P., who is an authority on matters connected with navigation, has turned his attention to this subject of marching by stars, and at the present time has an interesting and useful little booklet in the press, which also gives tables of star bearings for different latitudes. It will, I hope, soon be published.

One advantage of the time method is that no special instrument is required, and if a man has a watch he can mark out the bearings on a card, or make a note of them before he starts, as I shall show presently, and then march by them. Another advantage is that, provided the altitude is not too high, stars near the meridian can be used as well as those at a distance from it, which is frequently not the case with the altitude method. However, it is important to remember that the bearings are given in Colonel Tilney's tables for the local mean time, and this must therefore be approximately known. Still there is but little difficulty about this; for instance, if a man arrives at the front in France with a watch showing Greenwich mean time, all he has to do is to add the approximate longitude in time (about ten minutes), or put his watch on by this amount.

1st April. **LATITUDE 50° N.** ***1st April.***

Time	8 p.m.	9 p.m.	10 p.m.	11 p.m.	12 mid.	1 a.m.	2 a.m.	3 a.m.	4 a.m.	5 a.m.	Remarks.
REGULUS ...	145 E f N	170 E f N M P	170 W f N	145 W f N	125 W f N	110 W f N	100 W f N	85 W f N	Set 75 W f N		For Westerly Stars—see ALDEBARAN, SIRIUS, CAPELLA, PROCYON, CASTOR.
SPICA	Rising 110 E f N	125 E f N	135 E f N	150 E f N	165 E f N M	175 W f N P	160 W f N	145 W f N	130 W f N	120 W f N	
ARCTURUS ...	80 E f N	E	105 E f N	120 E f N	140 E f N	165 E f N M P	170 W f N	145 W f N	125 W f N	110 W f N	
ANTARES ...						Rising 145 E f N	155 E f N	170 E f N	Almost S M P	165 W f N	
VEGA	Rising 25 E f N	35 E f N	45 E f N	55 E f N	60 E f N	70 E f N	80 E f N	E	105 E f N	T H	
ALTAIR ...						Rising 80 E f N	95 E f N	105 E f N	120 E f N.	135 E f N	

LATITUDE 55° N.

REGULUS ...	150 E f N	170 E f N M P	170 W f N	150 W f N	130 W f N	115 W f N	100 W f N	W	Setting 75 W f N		
SPICA		125 E f N	140 E f N	155 E f N	170 E f N M	175 W f N P	160 W f N	145 W f N	130 W f N	120 W f N	
ARCTURUS ...	85 E f N	95 E f N	110 E f N	125 E f N	145 E f N	165 E f N M P	170 W f N	150 W f N	130 W f N	110 W f N	
ANTARES ...							Rising 155 E f N	170 E f N	Almost S M P	165 W f N	
VEGA	Rising 25 E f N	35 E f N	45 E f N	55 E f N	65 E f N	75 E f N	85 E f N	100 E f N	115 E f N	T H	
ALTAIR ...						Rising 85 E f N	95 E f N	110 E f N	125 E f N	140 E f N	

Remember Stars rise 2 hours earlier every month which is the same as half an hour earlier every week

Specimen Page of Colonel W. A. Tilney's Star Tables.

Attempts have been made by several persons interested to formulate general instructions for star marching applicable to a considerable extent of latitude, such as the whole of Central Europe, but many of these rules given are too rough and approximate to be of any use at all, and might mislead rather than help one to arrive at the desired destination. For instance, such a statement as "all stars rise in the east and set in the west," which I have more than once seen in books purporting to be guides to star marching, is most misleading, for most stars do not rise in the east at all, and if a man is facing a star that is rising in the north-east, his left arm will be 45° to the west of north.

Then again as regards the limits of latitude, true it is not necessary to have a separate table for every degree, but considerable error will arise if the same table is used for many degrees.

As I could not readily obtain the information with sufficient accuracy for the purpose from published tables, I worked out the other day, in view of this paper, what the difference in bearing would be for a difference in latitude of 5°, and I give these figures below :—

CHANGE IN BEARING DUE TO 5° CHANGE IN LATITUDE (N. LAT. 50° TO 55°).

Hour angle.	N. Declination 70°.	35°.	0°.	10° S. Declination.
0^h	0°	0°	0°	0°
3^h	5°·35	6°·21	1°·87	1°·17
6^h	2°·92	2°·35	0°	0°·62

From this it is clear that there is a considerable change in the bearings at certain hour angles if there is any great change in the latitude, and for them to be of any real value, even for such methods as we are dealing with, the same figures cannot be used without introducing considerable error for more than about 2° or so of latitude.

There is often a tendency to confuse the hour angle of a heavenly body with its azimuth or bearing, and to consider the change in these as the same. Not long ago a book was published in which appeared a statement which showed that the two were hopelessly mixed in the author's mind.

In this connection it may be interesting to see what sort of a change does actually take place in the bearing of stars for any interval of time, so I have worked out a table for lat. 50° N. for a change in time of 20^m with different declinations, those selected being 70° N., 35° N., 0°, and 10° S. The changes in bearing are for the changes in hour angle of 0^h to $0^h\ 20^m$, 3^h to $3^h\ 20^m$, and 6^h to $6^h\ 20^m$.

DIFFERENCE OF BEARING OF STARS FOR A DIFFERENCE IN HOUR ANGLE OF 20^m. (LAT. 50° N.).

Hour angles.	0^h to $0^h\ 20^m$.	3^h to $3^h\ 20^m$.	6^h to $6^h\ 20^m$.
Declination 70° N. ...	4°·97	1°·0	2°·03
,, 35° N. ...	16°·77	4°·73	3°·18
,, 0°	6°·51	4°·55	below horizon
,, 10° S. ...	5°·68	4°·48	,, ,,

From this it is clear that the change in the bearing is not at all the same thing as the change in time, nor do they vary in the same proportion.

Since by all methods of finding the bearings that depend upon the time or hour angle it is necessary to carry a watch, there seems no reason why the watch itself should not be turned into a compass, and if it could be arranged so that at any time when the hour hand is pointed at a known star, a definite line on the dial or marks on the dial automatically indicates the true north and south line, a useful star compass would be made from an ordinary watch without interfering with the latter. In fact it ought to be possible to use a watch as a star compass by some simple addition that could be easily and inexpensively fitted to one of ordinary make.

There is already the well-known way of using a watch for finding approximately the north and south line by the sun, and my idea was to make some arrangement so that the same kind of thing could be done by using certain of the brightest stars.

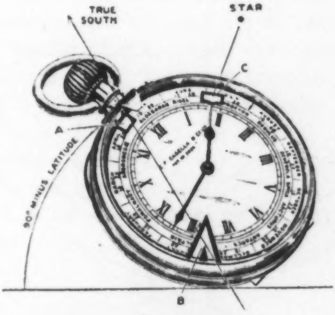


FIG. 7.

The result of my endeavours and experiments in this direction will be found in the "Night Marching Watch" (Fig. 7), which was described in the *Geographical Journal* for April 1913.

It would take too long now to give a detailed explanation, but briefly the scheme consists of adding two movable concentric circles to the dial of the watch, outside the hour circle, a luminous point to the hour hand, and two other luminous marks of radium paint to the circles. By a simple setting of the circles for a suitable star, the names of which are given on one of the circles, it is so arranged that, when the hour hand with the luminous point is directed towards the star, and the watch held roughly at an angle equal to the latitude of the place, the other two luminous marks indicate the north and south line, or can be set on to any bearing upon which it is desired to march.

This compass watch has been throughly tested and found useful; one traveller got the navigating officer on board the ship in which he was travelling to America to compare it during the voyage with the bearings given by the ship's compass, of course making allowance for the variation, and he wrote afterwards to tell me that the results were most satisfactory.

The second way of obtaining the true bearing of a star is from its altitude above the horizon line. In all accurate survey work this altitude is carefully measured with a theodolite and the bearing or azimuth (the angle PZ✱, Fig. 6) computed by spherical trigonometry. Now a soldier on a night march is not going to carry a theodolite about with him, but if he can take a rough shot at the star even with a small clinometer, giving the altitude to the nearest degree, there is no reason why he should not obtain a bearing that will be quite useful for marching on, except when the star is close to the meridian; and this method would have the advantage of doing away with the necessity of carrying a watch, since no time is required.

A short time ago I looked into this matter to see what could be done, with a view to making some simple clinometer that would give the bearings of stars corresponding to any altitudes, instead of the altitude itself as is the case with an ordinary clinometer, and I came to the conclusion that it is quite possible to do so. Fig. 8 shows a clinometer of this kind.

I cut a semicircular piece of card, and marked out, for lat. 50°, the true bearings from the north point of the horizon of Altair on one side and Vega on the other, corresponding with the angles of altitude, so that when a rough altitude is measured in the ordinary way, the silk, at the end of which is a bead to serve as a plumb-bob, cuts the bearing of the star at the time. The bearings can, if desired, be marked with luminous paint so that they could be read at night. I have tested this simple little arrangement and found it very fairly accurate. As I have shown, it could be used within a degree or two on either side of the latitude of 50° N., and so would serve for the whole of the British field of operation in France. Clinometers of this kind could be made of celluloid or any other suitable material at insignificant expense, and about half a dozen of them, with two stars on each, would be all that is required. The number could, of course, be reduced by having two concentric arcs on each side, so that one protractor would serve for four stars, as shown in Fig. 8. Any ordinary clinometer could be adapted.

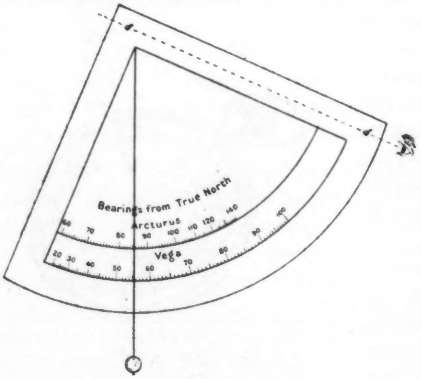


FIG. 8.

In order to show what sort of error is likely to be produced in the bearing by taking such rough altitudes as here referred to I have computed the approximate changes produced in the bearing by a supposed error of 2° in the altitude, which is about twice as large as may reasonably be expected, since it is a very bad clinometer that will not give altitudes true to one degree. However, taking the error at 2° the following are the results :—

DIFFERENCES IN BEARING DUE TO A SUPPOSED ERROR OF 2° IN THE MEASURED ALTITUDE (LAT. 50° N.).

	Approx. hour angles.			
	0^h	1^h	3^h	6^h
Declination 70° N. ...	Indefinitely large	17°·7	2°·7	1°·1
,, 35° N. ...	,,	11°·7	3°·1	2°·1
,, 0	,,	5°·6	3°·8	2°·4
,, 10° S. ...	,,	8°·1	3°·8	Star below horizon

From this it is clear that to be sufficiently accurate the altitudes must not be taken when the hour angles are very small, and the only safe rule is to take them when the stars are at a considerable distance from the meridian. Stars with a high declination, such as Vega, are in this latitude much too near the zenith for finding directions when near the meridian, so in any case they would not be used. It is easy to see if the star is east or west of the meridian by noting whether their altitudes are getting higher or lower as time goes on.

Soon after I had my attention specially turned to the importance of using stars for night marching I designed what is called the "Astronomical Compass," which was described in the *Geographical Journal* for December 1908. As this little instrument has now been used a good deal in various parts of the world, probably some of you are acquainted with it, so I shall not detain you by attempting to give a detailed description of it here. However, I will briefly explain how it is used for finding star bearings and marching purposes. It has other uses as well, such as giving the time, but I will only deal with it now as a star compass.

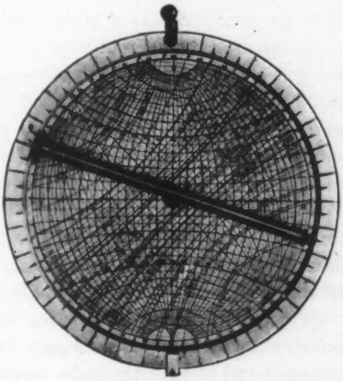


FIG. 9.

The instrument (Fig. 9) consists of two discs upon each of which is a projection of a hemisphere drawn on the plane of the meridian. One of the discs shows, in black, parallels of declination of the principal stars with hour circles, while the other, the upper one, is transparent, and shows in red, curves of altitude and azimuth. The two discs are centred on a pivot on which they can be revolved, and the transparent one is weighted at the lower part to keep it vertical. Through the pivot passes a pin carrying a sight-rule on the front of the transparent disc, and fixed to the handle at the back. When the instrument is used for finding star bearings, the north pole of the black declination circle is first set to the red number on the transparent disc at an angle equal to the latitude of the place; then allowing the discs to swing freely, clamped together, a rough altitude of the star is taken by means of the sight-rule. The red altitude circle on the transparent disc, indicated by the pointer at one end of the sight-rule, is now followed across the disc until it intersects the black curve of declination of the star observed, seen through the transparent disc, and then the red longitudinal curve passing through the point of intersection gives the bearing of the star. The compass can be also used for marching by setting the bearing on the circumference of the disc, and then placing it horizontal, and pointing the sight-rule at the star. When this is done the north and south line will be shown by the central red arrow on the disc. Luminous paint renders it possible to see the circles and marks at night. With this instrument altitudes and bearings can be read to the nearest degree and no tables whatever are required. It can also be used for finding the bearing when the hour angle is given, and many have told me that it has proved of great service to them, although of course too much must not be expected from any arrangement of this sort.

It is not necessary that the instrument itself should be carried on a rapid march, as the bearings of a suitable star can be taken off for the required times and noted down beforehand.

The greater part of this paper has so far been taken up with different methods of finding the bearings of stars at any time, and now we must pass on to the practical part of using these bearings in marching.

There are two different ways of using stars in night marching, and that which is generally given in handbooks is to treat them as marks to indicate the bearings previously ascertained by means of a prismatic compass, and march on them just as one would use distant hilltops or any other prominent terrestrial objects for the purpose in the daytime. This is simple enough, and does not even necessitate a knowledge of the name of the star. It is important to be sure that a star at a suitable altitude and position in the heavens is used, and that there is no mistaking it for another after starting on the march. It should be as near the direction of the route as possible, and preferably a few degrees to the east of the route at the commencement to allow for its movement, which might take it inconveniently far away as time goes on. The time during which a star may be considered to have the same bearing depends upon its position, but as a rule it is safe to take it as about 15 minutes or even longer under favourable conditions. There is no need to have the star right on the line of march, as it is easy to measure with sufficient accuracy the number of degrees round the horizon between a vertical line under the star and the required direction, provided the angle is not very large. The angle subtended by the length of the ordinary easy span from the end of the thumb to that of the middle finger may be taken as 15°, so if a man has no other means of measuring an angle round the horizon he can stretch out his arm and roughly span out the required number of degrees in this way. It will be convenient to know the length of various parts of the rifle in inches or to carry a stick marked in inches, for then when this is held in the centre by the clenched fist at arm's length, the angles subtended are easily known and committed to memory from the following table :—

2 inches may be considered to subtend an angle of 5 degrees
4 ,, ,, ,, ,, ,, ,, 10 ,,
6 ,, ,, ,, ,, ,, ,, 15 ,,
8 ,, ,, ,, ,, ,, ,, 20 ,,
10 ,, ,, ,, ,, ,, ,, 25 ,,
12 ,, ,, ,, ,, ,, ,, 30 ,,

Clear and concise instructions for combination star and compass marching are given in the official Manual of Map Reading and Field Sketching, and in other books, so nothing more need be said here.

It is important in this and in any other system of star marching to make good use of features such as junctions of streams, lakes, hills, etc., as they are approached sufficiently close to become visible to check the bearings and distances, just as a navigator verifies his position at sea whenever an opportunity occurs by headlands, soundings, and any means of the kind available.

A very good example of a star march combined with or without a compass is given in Major H. Maclear's useful little booklet on 'Night-Marching by the Stars' which appeared last year, and which I was asked by the author to look through when in proof form. I have ventured to make a slide from the example which I will now show on the screen (Fig. 10).

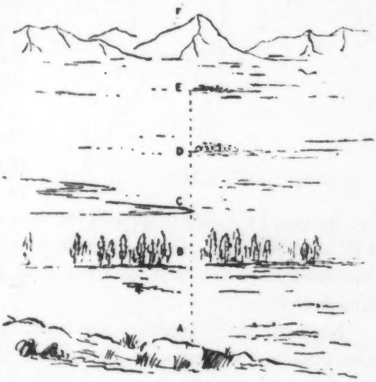


Fig. 10.

It is desired to march from A to E, a fortified village which has to be surprised by night. The line has been reconnoitred by day, the compass bearing of E taken, and the positions of prominent features noted down. At night when the march is commenced a suitable star is selected near the line of march, or a little to the east of it, and the march commenced. The distance between the points have been ascertained roughly from some sketch-map or other information, so the position at any time during the march is fairly well known, and can be checked by the land features as they are reached.

By the second method of star marching no magnetic compass is used at all. The bearings of the stars for suitable times during which the march is to take place are taken out from Colonel Tilney's tables, by the astronomical compass or some other means, and are jotted down, with the times and the route regulated accordingly, as previously shown.

Sometimes it is convenient to construct a bearing card like that shown in Fig. 11 before starting on the march. The lines can be marked by luminous paint, or by sticking pins on the various lines. All that is necessary then is to hold the card horizontal and to place the line of star bearing for any time in the direction of or vertically under the star, and march on the bold line indicating the direction of the route.

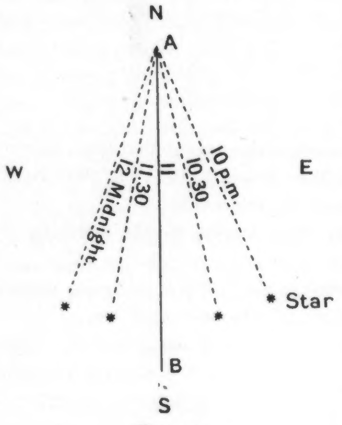


Fig. 11.

So far the route has been supposed to follow a straight line, but it is hardly likely to do this for any length of time, so I will close by giving an example of a march with changing directions and bearings.

Let it be supposed that a party has to march at night from A to B (Fig. 12). Before starting the route to be taken is roughly sketched out on the best available map, and the true bearings from the south measured with a protractor. If the ground is entirely unknown, the route must be reconnoitred in the daytime from compass bearings and time and a route map drawn.

Next the star's bearings are taken from the tables as before, or otherwise obtained as described for suitable times, which are here 10^h, $10^h\ 15^m$, $10^h\ 30^m$, and $10^h\ 45^m$.

These star bearings are plotted out as shown on the example, and together with the bearings of different sections of the route, give the bearings to be followed during the march. For instance, from 10^h, when the march commences, to 10.15, the 10 o'clock bearing is followed; that is the star is kept 14° to the left of the route; from 10.15 to 10.30 the 10.15 bearing is followed, and the star kept 28° to the right of the route, and so on.

When the march is actually taking place all that is necessary is to have a note of the bearings to be followed at different times, and change them as these times arrive. A watch is, of course, necessary to give the times. If the bearings and times are not many they could be committed to memory beforehand. The bearings are taken at quarter-hour intervals, which would be near enough for the purpose, as the differences are only about 3° or 3½°. If the difference had been greater or the bearings had been taken out for longer intervals, it would have been well to have used the bearing of the star for the time midway between the times of the commencement and termination of the various sections of the route, which would have helped to balance the error. The following table gives the error in yards on either one side or other of the correct point for various degrees of error in bearing after a distance of 2 miles.

9 Feb. 1916. Star, Rigel

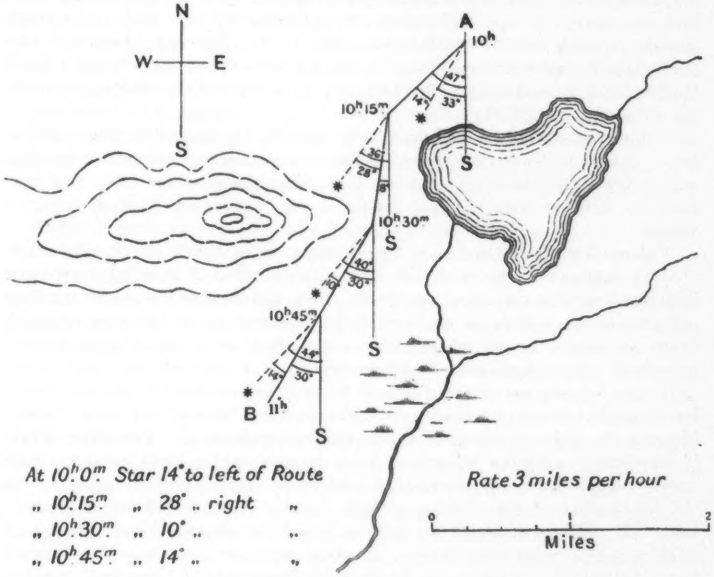


FIG. 12.

1° error = 61·2 yards.
2° " = 122·9 "
3° " = 184·4 "
4° " = 246·1 "
5° " = 307·9 "

By estimating the rate of march, the times when each change of the route is arrived at can of course be noted down beforehand. In this example the rate is supposed to be 3 miles per hour.

Lieut. HOLROYD: What has chiefly struck me during Mr. Reeves' lecture is that probably not one officer in twelve knows his stars. It was only last autumn that I began to learn my stars. I thought it might be as well to spend a few weeks or months of convalescence in finding out the principal stars; it took me less than a week. One's first notion is that the stars are a big and complicated subject, but if people realized how simple it is to learn the general shape of the constellations, many more would do it.

The method by which I taught myself was to get a star-map and a piece of brown paper and four sizes of pins, and prick holes in the paper to represent the stars according to their different magnitudes and relative positions; thus I mapped out the northern sky. I started with the pole in the centre, and as I got out to the edge of the paper, gradually the shape became wrong, and I had to enlarge the spaces between the constellations. It took me a single evening to prick out the constellations, that is the chief ones, down to a little south of the Equator; and when I went out into the night I found I knew them. Held up to the light, the dark paper pierced with pinholes gave much the effect of the night sky.

I think that would be the best way to get over the great difficulty, which is to get people to learn the general shape of the constellations, just as the best way to learn the shape of a country is to draw a map of it. Once you have got those first few stars, the rest, thanks to Mr. Reeves and Colonel Tilney, is simple.

Colonel TILNEY: Some time ago I read a paper before the Royal Society of Arts announcing the perfection of an easy method of enabling troops and individual men to find their way by the stars, and discussing the far-reaching influence of the system on night warfare. A knowledge of the position of the brightest stars in the sky brings about a revolution in the possibilities of night movement and operations. Fourteen years ago I foresaw that most of the important fighting in modern war must be at night, and that if we could devise some simple method of teaching all ranks to know their way at night it would improve the fighting efficiency of the army a hundredfold. The object I had in view was to solve the problem of knowing your way at night without a map, watch, compass, or any instrument whatever. This has been attained by the publication of the 'Soldier's Night Guide' (Gale & Polden, Aldershot) price 3*d*., editions of which are now published for almost all latitudes, which enables troops to get their general direction from the heavens. For accurate work, 'Marching or Flying by Night, with Time-table of Direction Stars,' is now complete for most countries of the world (Hugh Rees, 5, Regent Street, London, price 1*s*.).

I little thought that we should be able to solve the problem so satisfactorily, and I take this opportunity of expressing my deep gratitude to Mr. Reeves for his help and kindness; nor must I forget Captain Blackburne, the nautical adviser to the New Zealand Government, who was always ready to assist me in India. After many failures and vicissitudes we have conquered the night and thereby revolutionized warfare. To many of you this may appear to be an exaggeration, but I have received reports from many parts of the country, as well as from abroad, of the far-reaching influence this knowledge of the stars must have on almost every branch of the service.

Mr. A. R. HINKS: I should like to accentuate in the first place what Mr. Reeves has said: that the method of night marching by stars should be looked upon as only one of several methods available, and especially as one which is not always available. From that point of view I cannot help thinking that Colonel Tilney has perhaps exaggerated the merits of night marching by stars, because it will be seen that the first time one wants to go on a night march on a really favourable night—when there are no stars—he will have to fall back upon our old friend the magnetic compass. There are a very large number of methods of employing the stars and the compass to set one another off—of employing the stars to enable you to use your compass, to check your compass, even to march on if you lose or break your compass. But the man who will understand how to make the best use of these is the man who knows the many different methods and the way they are involved, so that if one fails he can fall back on another. It seems to me a pity to lay too much emphasis on night marching by stars as a great discovery, for it is nothing new, though it may not have been enough practised. At any rate some ten years ago the late Captain Bertrand Stewart, who was well known to many of you as a very keen yeomanry officer, and who at that time was bringing out the "Active Service Pocket-Book," wrote to my old chief and asked if he could advise him on methods of marching by the sun and the stars. The matter was handed over to me, and we invented "star compasses" and "sun compasses," which are to be found in that book. I am not at all sure that these star compasses and sun compasses have any particular merit. There is nothing particularly new in the idea, and there are fifty ways of doing the thing, some of which Mr. Reeves has described in his interesting paper.

There is one thing that Captain Stewart's book tried to do, very roughly, that has not generally been done, and that is give an indication how to use the moon for marching on. The moon is the most erratic body in the sky, and not only moves very irregularly in its orbit, but is inclined to the ecliptic, and, generally speaking, it is not very easy to get any useful sort of simple rules. On the other hand, it would be extremely valuable to use. There are many nights when one can see the moon, but not the stars, through fog or broken cloud. I would like to suggest that it would be quite easy with some such instrument as Mr. Reeves' Astronomical Compass to plot out in advance the bearings of the moon for any particular nights and times. That is a thing that, of course, you would not expect a private soldier to do; but might it not be considered as a legitimate part of staff work, whenever there was any important operation on hand? The preparation of a little table of the bearing of the moon for every quarter of an hour is not a complicated matter.

I should like to say a word about the general accuracy of these methods of marching by stars. It has struck me while listening to Mr. Reeves, and more forcibly while Colonel Tilney was speaking, that one might very legitimately aim at considerably greater accuracy than they have provided. When I was at Cambridge I was interested in the work of the Officers' Training Corps, and used to arrange marching competitions, which consisted of the simple exercise of starting teams to march straight across country upon a given bearing for 2 or 3 miles. A challenge cup was given to the company team which kept this bearing best. This march was done, of course, with the luminous prismatic compass of the old pattern, and I was always interested to work out what was the probable error of a march under such conditions. Experience of a considerable number of competitions showed that the probable error was 1½°. If you started eight teams marching upon a given compass bearing, the probability was that four would be inside 1½° of the truth and four outside it. That suggests that if you are going to use your stars as aids to compass marching you must not be quite so tolerant of their motion in azimuth as Colonel Tilney would be, because in fifteen or twenty minutes a star may move 4° or 5° or more. You should bear in mind that the star is moving at the rate of a degree in so many minutes; or at any rate allow for the gradual drift of the star if you are marching anywhere towards north or south. East and west it is less important. It is worth while, I think, to aim at a higher degree of accuracy than Colonel Tilney aims at. He said, for example, that on the Tigris the stars rise vertically, so they maintain each its constant azimuth. That must not be taken too literally. They will rise at a slope of 25° to the vertical, and so will have a considerable motion in azimuth. I should like to see tables such as those of Colonel Tilney given to the nearest degree instead of to the nearest 5°. It would encourage people to aim at an accuracy that is by no means outside what can be achieved.

Captain L. A. W. **Brooks**, R.F.A.: I understood from the lecturer this afternoon that if the arm is held out at full length the span of the fingers would be about 15°. Is that accurate? We have always been taught that the calibration of the "span of the fingers" when the arm is held at arm's length is 19°. The difference in traversing 4 miles would, of course, give an error of 246 yards, which is more than ten per cent., and it would be quite obvious to any one that after a march of say 15 to 20 miles at night-time the approximate difference would be very greatly increased in ratio to the distance covered. I should like to ask if the calibration approximates more closely to 19° than 15°.

Mr. **Reeves**: The angle subtended by the span at arm's length must, of course, depend upon the length of a man's arm and the size of his hand, but as an average it may, I think, be taken as about 15°, on the supposition that the length of an easy natural span from the tip of the thumb to that of the middle finger is 6 inches. It could certainly be stretched to a greater length. From the tip of the thumb to that of the little finger would subtend a larger angle, say about 18° or 19°. These are the figures I have seen in books, and from trial I have found them about right.

Dr. J. W. **Evans**: I must congratulate Mr. Reeves in giving us another example of his ingenuity and originality. There is, however, one point he did not bring before us, which is that the choice of the method to be employed in determining the azimuth or bearing of a star must depend very largely on the latitude. He obtains the azimuth either from the hour angle or the altitude. In high latitudes the altitude cannot be employed, because it varies very little; the observer must therefore resort to the hour angle. Near the equator, on the other hand, the altitude changes rapidly, and a considerable alteration in altitude is accompanied by only a small variation in the bearing. Consequently the simpler method in which the bearing is deduced from the altitude is to be preferred.

There is another method which might, I think, prove convenient except near the poles. Instead of taking the altitude of one star, the apparent inclination of the imaginary line joining two neighbouring stars might be taken. Two very simple examples will explain the principle. At a latitude of 10° to 15° south, wherever the Great Bear appears at certain times above the horizon but the pole star is not visible, we know that when the pointers are vertical they are due north of the observer. Again, if in the north of India α and β Centauri are seen in a horizontal position, they will be situated due south.

There would be no difficulty in constructing a table for any particular latitude showing the relation of the inclination of two stars to the azimuth of one of them.

[*Note.*—The azimuths and co-altitudes of both stars will first be calculated from the co-latitude and their co-declinations and hour angles. The apparent inclination of the line joining them is then given by the formula—

$$\tan \kappa = \frac{\cot \beta_1 - \cot \beta_2}{2 \sin \frac{1}{2}(\alpha_1 - \alpha_2)} = \frac{-\sin (\beta_1 - \beta_2)}{2 \sin \beta_1 \sin \beta_2 \sin \frac{1}{2}(\alpha_1 - \alpha_2)}$$

where κ = the inclination required ; α_1, α_2 the azimuth, and β_1, β_2 the co-altitudes of the stars. It is obvious that tan κ will be + when the line joining the stars slopes upwards from the first to the second, provided they are numbered in the direction in which the azimuth is measured.]

The principle of the clinometer described by Mr. Reeves might be utilized for this method. The card would have concentric circles drawn upon it in exactly the same manner, but the graduations showing the bearing of one of the stars would be determined not by the altitude of that star but by the apparent inclination of the two stars. Such a card would be easier to use. Mr. Reeves, in his altitude method, looks along the edge of the card at the star, but I do not know exactly how he reads the position of the plumb-line at the same time. Probably he gets an assistant to do it. If, however, an observer determines the inclination of two stars by holding it so that they seem to lie on its upper edge, he can simultaneously observe the position of the plumb-line.

Mr. REEVES : The method of finding the azimuth by the inclination of two stars as suggested by Dr. Evans is decidedly interesting, and I should like to see clinometers such as he suggests constructed for different latitudes, as under suitable conditions they would doubtless be useful. Of course, it would mean that the two special stars must be visible at the same time instead of one only, and with our cloudy skies this might frequently be impossible. I hardly think that such a clinometer would be easier to use than one depending upon the altitude of a single star, and I have found that the whole operation of obtaining the azimuth with the latter only occupies a few seconds. There is no difficulty in reading the azimuth off the scale. When the star is sighted, and the thread with the plumb-bob is steady, by a quick turn of the clinometer over to the side opposite to that on which the thread hangs, the weight at the end holds the thread firm until the azimuth can be read. Many suitable clamping arrangements could be suggested, and most of those already in use in ordinary clinometers would serve the purpose quite well.

Colonel TILNEY: May I just say a few words in reply to what Mr. Hinks has said? All that I did wish to suggest was that the natural compass in the heavens would be of the greatest possible utility to men fighting at night. I want also to say to Mr. Hinks that what I aimed to start with was to make all men, not only an officer with a compass, know their way. I believe that the key to success in night warfare is for all ranks to know their way at night. The only manner in which this end can be attained is to teach the rank and file, who have no compasses, how to read the sky. It has been proved beyond a shadow of doubt that if men get into the habit of observing their direction by the stars, they instinctively acquire a sense of direction, so that they find their way by terrestrial objects when no stars are visible. Once you instil into troops this sense of direction most difficulties connected with night operations are removed : (i.) The men are confident and self-reliant ; (ii.) they will not fire and dig trenches in the wrong direction ; (iii.) all communications will be much facilitated ; (iv.) in night attacks or retirements, all ranks will know the direction of advance or retirement ; (v.) slightly wounded men, able to walk, know their way back to the dressing station ; (vi.) it was proved in India that troops can be manœuvred with ease, rapidity, and accuracy on a starlight night. Many other obvious advantages might be given.

With regard to Mr. Hinks' criticism that we should try for a greater degree of accuracy, I would refer him to our first effort to solve this problem which was published in 1909, 'Rapid Night Marching made easy' (Stanford, Long Acre, London, price 2*s.* 6*d.*).

The systems explained therein enabled you to get any star's bearing accurately for any hour or latitude ; it was thoroughly tested in India, South Africa, and at home, and except for artillery purposes this extreme accuracy was found to be altogether unnecessary. As Mr. Reeves points out, the present tables can be read to within 2° of accuracy for any hour of the night.

The **President**: I am afraid our subject to-night is not one on which I can make any serious contribution to knowledge. In my travels my regards have been rather earthly than heavenly. One has, perhaps, been too much inclined to look upon star-gazing as a romantic pursuit. It is a good thing that we should be taught to appreciate its practical uses. The reason why we have been so slow to do so may be that in this country we live in such a misty climate, and it is practically only one night in three that you have any stars to steer by. I must confess that I have never steered my course by the stars, but I was a little surprised to hear marching by stars spoken of as being novel. It has surely long been the practice among "simple people." In every new discovery, or new form of invention, when we look back we find there are predecessors in some rudimentary form. There were balloons in the skies before there were Zeppelins. We have heard to-night of a method which ensures a practical advance, and may be extremely useful particularly to armies who have to fight, happily or unhappily, under the burning suns and the brilliant stars of Eastern lands. I am sure you will agree with me in wishing to thank Mr. Reeves warmly for the trouble he has taken, for the excellent diagrams he has shown, and for the clear way in which he has put this matter before us.

Note.—In subsequent conversation with Colonel Tilney I have realized that his aims are different from what I had supposed when he spoke. He is not really concerned with training troops to march as accurately as possible by the stars, but has the simpler and no doubt exceedingly important object of showing every man how he can, in a rough and ready way, learn the points of the compass and so keep his direction at night. This is of course quite a different matter from what Mr. Reeves and I were speaking of. It is doubtless quite true that the average man enlisted into the army, often a town dweller and always accustomed to move about on known roads, has little or no idea of keeping the points of the compass in his head.

I am still disposed to think that Colonel Tilney would do well in future editions of his tables to give the azimuth to the nearest degree, so that the motions of the stars in azimuth at different times at night may be better represented. It is somewhat confusing to any one who wishes to go beyond the most elementary use of the stars to find them as represented as moving perhaps 10° in azimuth in one period of two hours, and 0° in the next period.—
A. R. H.